Extending the Economic Model of Crime to Environmental Offenses - and vice versa

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Abstract

Violations of environmental laws or regulations fall into a wide range of severity. Whether any specific violation is classified as a minor misdemeanor or a serious criminal act is, however, a choice made by legislators and/or regulators. Increasingly, policy-makers have resorted to instruments associated with the prosecution of criminal acts in order to regulate environmental offenses. This increasing use makes the literature on the economics of crime more and more relevant to the analysis of environmental regulations. It is the aim of this paper now to provide a starting point for an analysis of the intersection of both the literature on environmental regulation and on crime. By doing so, I provide a contribution to a broader discussion of both, environmental offenses and the economic model of crime.

JEL classification: K32; K42; Q58

1 Introduction

Almost four decades have elapsed since Becker (1968) published his seminal article, introducing what is commonly called the economic model of crime. Since then there emerged a vast theoretical and empirical literature applying Becker's (1968) model to many types of crime and extending it in various directions[1].

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[1] see Polinsky & Shavell (2000/2005) for a quite comprehensive overview .

Moreover, Becker's (1968) model of crime was also the starting point for the analysis of firms compliance with environmental regulations and the associated enforcement efforts of related governmental institutions. In these models, however, non-compliance is rather treated as a simple regulatory misdemeanor than a serious crime. Since the amount of environmental laws which define particular environmental offenses as crime is rising steadily in most western countries[2], it seems to be appropriate to reconnect both models in order to account for changing realities.

Although Becker's (1968) model of crime builds the basis for the analysis of environmental regulations, several adjustments have been made to account for the special characteristics enforcement has in this setting. Institutions ensuring compliance with environmental regulations have at least to some extend different mechanisms at hand to interact with potential offenders. As more recently, however, environmental law more and more applies instruments usually belonging rather to the prosecution of crimes than to enforcement of environmental regulations, the question in this paper is, how these different mechanisms can be incorporated into one approach.

Furthermore, thinking the other way round, most of the research dealing with the economic model of crime only stresses serious crimes like felonies or serious property crimes. It is therefore not only the case that monitoring and enforcement (M&E) literature neglected the analysis of more serious environmental offenses, also crime literature did not consider the analysis of less serious violations. However, and as already suggested by Becker (1968), the economic model of crime should be valid for all kinds of legal violations.

The aim of this paper is to provide a starting point for an analysis of the intersection of both the literature on environmental regulation and on crime. By doing so, I provide a contribution to a broader discussion of both environmental offenses and crime. Environmental offenses, similar to tax evasion, seem to be a very good topic for this purpose since the transition from a simple misdemeanor to a real crime is often very fluent in both cases, at least in Germany.

The remainder of the paper is organized as follows. Section two will focus on the discussion of the economic model of crime and the model used in enforcement and compliance literature. Both models will be contrasted and similarities and differences will be highlighted. The last part of section two

[2] in the U.S. some EPA officers even carry handguns and are allowed to arrest people (see Cohen, 1999)

tries to pave the way in order to find possible bridges for the existing gap between the two. Section three will focus on empirical evidence found so far for the economic model of crime as well as for the discussion on enforcement and compliance with environmental regulations. This includes also an examination of important policy variables and their empirical relevance. Special interest will here be in different deterrence variables and their observed effectiveness. Section four will give a brief introduction to the peculiarities of German environmental law and shows why it is especially appropriate for our purposes. Finally, section five gives a overview of what has to be done in future to bring the two fields together.

2 From the economic model of crime to the literature on M&E of environmental regulations

As Heyes (2000) already points out, the models used to explain the efforts made by legal authorities to enforce environmental regulations and the resulting compliance or non-compliance of related firms are based on the economic model of crime introduced by Becker (1968). However, environmental economists made several adjustments in order to account for the special characteristics environmental regulations and related enforcement institutions have. It is now the aim of this section to find ways how to both re-adjust the model used in the enforcement and compliance literature and to extend the economic model of crime such that one can map the hole range of severity environmental offenses may have. I will therefore first of all review the basic economic model of crime and then go on and derive the model used in enforcement and compliance literature. The last part will then be a first try to close the gap between the two.

2.1 The economic model of crime

Becker‘s (1968) model of crime is a model of individual behavior. In its simplest form it solely argues that someone will commit a crime or violate some legal rule if the gain through this exceeds its costs in terms of expected punishment. A potential criminal is therefore seen as a rational individual maximizing its utility.

In contrast, there are other theories around trying to stick some sort of mental diseases to criminal behavior[3]. Unlike this other theories, however, Becker's (1968) model discloses society a comprehensive amount of possibilities to prevent (at least some) people from harmful activities[4]. With this economic model of crime, society has just to ensure that expected costs exceed the awaited benefit[5].

More formally, following Polinsky & Shavell (2000/2005), a risk neutral individual will commit a crime or violation, if:

$$g > p(f + d(t)),$$

with

g = gain an individual obtains from illegal activity;

p = probability of detection[6];

f = possible[7] fine for specific violation , f ϵ [0,f_{max}][8];

t = possible[8] length of imprisonment term for specific violation, t ϵ [0,t_{max}][9];

d(t) = disutility per unit of imprisonment term t; d(0)=0; $d'(t) > 0$.[10]

As already stated above, this model experienced numerous extensions. However, interesting extensions for our purpose include variables for the

[3]Levitt & Miles (2004) list a few examples of related work.

[4]Assuming that criminals are driven by some mental disease makes deterrence rather difficult. A individual who is addicted by criminal behavior will most likely not be deterred by more police or a more severe punishment.

[5]of course it will be rarely the case that society is able to ensure that resulting costs allways exceed benefits for all persons and all crimes. This is just because of budget constraints society faces when financing enforcement (police, prosecution, courts, prisons, etc.).

[6]Including the possibility of a dark figure into this model, p can be broken down into: $p = \frac{C}{N} = \frac{C}{Q-V}$,with: C = amount of criminals being detected; N = amount of recorded violations; Q = total amount of crime; V = dark figure.

[7]legal systems usually do not provide a fine or imprisonment term for every violation, one commonly does not have to pay a fine for murder (there are exceptions, see the essay of the Economist [Dez. 2006] for the codex of Pushtunwali) and one commonly does not have to go to prison for red light running.

[8]f_{max} may be at the individual wealth constraint of the offender.

[9]t_{max} may differ from crime to crime with the absolute maximum being a lifelong prison sentence.

[10]d() should rise proportional to s, i.e. d(s)=s, if the individual is risk neutral in imprisonment term, see Polinsky & Shavell (2000/2005).

probability of getting a fine p_m and being arrested p_a and functions for f and t that depend on the severity of the crime s (marginal deterrence)[11]. Furthermore, the particular probabilities may depend on the expenditures e for police, prosecution, courts or other public enforcement agencies and on the severity of the crime s.

It is likely the case that the probability of detection p_d will be a function of the expenditures for police and other public institutions detecting legal violations. In the same manner the probability of getting a fine may depend on the expenditures for prosecution and for courts. Finally, the probability of arrest may depend amongst others on the expenditures for prisons and all probabilities may, as already stated, depend on the severity of the committed crime. Finally, the severity of the violation is also meant to influence the gain for the criminal.

Putting all this together, one can write the economic model of crime more elaborate as

$$g(s) > p_d(s,e)[p_m(s,e)f(s) + p_a(s,e)d(t(s))],$$

Additionally, one presumes that gain g, fine f, imprisonment term t and imprisonment disutility d rise with increasing the severity of violation[12]. Furthermore, the probabilities of detection, getting a fine and getting arrested rise with both enforcement expenditures and severity of the violation[13].

Although it should be obvious why the probabilities of getting a fine or arrested are assumed to rise with severity of the crime, it may not be obvious for the probability of detection. However, the more severe the crime, the more efforts will be made to detect the offender (see Polinsky & Shavell 2000, p. 63). As an example one has just to think of the insertion of special forces to free hostages or to arrest serial killers. As this may not hold for all types of crimes I assume that the probability of being detected will at least not decrease with severity of the crime.

In the economics of crime literature there is also a great discussion on welfare effects of public enforcement activities[14]. This is not a topic I want

[11] there are a lot more extensions, see Polinsky & Shavell (2000/2005); I will focus on those relevant for the analysis of individual behavior with respect to environmental law.

[12] more formally, this means: $\frac{\Delta g}{\Delta s} > 0$, $\frac{\Delta f}{\Delta s} > 0$, $\frac{\Delta t}{\Delta s} > 0$, and finally, $\frac{\Delta d}{\Delta s} = \frac{\Delta d}{\Delta t}\frac{\Delta t}{\Delta s} > 0$.

[13] more formally: $\frac{\Delta p_D}{\Delta e} > 0$, $\frac{\Delta p_D}{\Delta s} \geq 0$, $\frac{\Delta p_m}{\Delta e} > 0$, $\frac{\Delta p_m}{\Delta s} > 0$, $\frac{\Delta p_a}{\Delta e} > 0$, $\frac{\Delta p_a}{\Delta s} > 0$,

[14] see Polinksy & Shavell (2000/2005)

to discuss here, the focus here will be on the individual decision to commit or not to commit a crime or violation.

2.2 The model on enforcement and compliance

Following Heyes (2000), the basic model used to describe firms behavior concerning environmental regulations is nothing else than the economic model of crime. Firms facing environmental regulations just minimize the sum of compliance cost and expected penalties. Speaking differently, this means that a risk neutral firm chooses to comply or not to comply, respectively, if:

$$\text{c} \leq \text{p}\cdot\text{f} \quad \text{or} \quad \text{c} > \text{p}\cdot\text{f},$$

with c as the cost of compliance with a particular regulation. That is, a firm will violate a regulation if the gain[15] through this violation exceeds the expected costs. This shows that the basic idea is nearly identical to the economic model of crime. As we will see in next section, there may arise some problems when comparing the individual setup of the economic model of crime with the behavior of a firm usually analyzed when dealing with environmental regulations.

However, as Heyes (2000) already points out, many decisions regarding compliance with environmental regulations are not binary ones as described above but rather continuous ones. This may be modelled by letting f depend on the actual amount of pollution s and some standard S. This means that f(s,S)=0 $\forall s \leq S$ and f(s,S)>0 $\forall s > S$, respectively[16]. Additionally, $\forall s > S$ one presumes that $\frac{\Delta f(s,S)}{\Delta s} > 0$ and $\frac{\Delta f(s,S)}{\Delta S} < 0$.

Moreover, in the binary case c then will reflect the abatement costs a(s,S) to comply with S when emitting s, assuming a(s,S)>0 $\forall s > S$. Therefore a firm will not comply, if

$$\text{a(s,S)}>\text{p}\cdot\text{f(s,S) with } \frac{\Delta a(s,S)}{\Delta s} > 0 \text{ and } \frac{\Delta a(s,S)}{\Delta S} < 0.$$

Furthermore, the amount of non-compliance will depend on marginal deterrence and on marginal abatement costs, i.e. if non-compliant a firm will choose a point, where

[15] actually, there is often no direct gain from violating a regulation, its more saving compliance costs (that is compliance costs can be seen as negative opportunity costs g = 0 -(-c) = c) .

[16] as long as there is no type II error, see Heyes (2000)

$$\frac{\Delta a(s,S)}{\Delta s} = p\frac{\Delta f(s,S)}{\Delta s}$$

for a fixed pollution standard S.

As in the Becker model, there probably is an upper bound for f() which is either some practical or political limit or the wealth constraint of the particular firm (see Heyes, 2000).

A further extension, again very similar to the economic model of crime, includes the "endogeneity" of "inspectability" as Heyes (2000) calls it. This is nothing else than p depending on pollution level s, standard S and public expenditures e, p(s,S,e), with $\frac{\Delta p(s,S,e)}{\Delta s} > 0 \ \forall s > S$ and $\frac{\Delta p(s,S,e)}{\Delta e} > 0$. This could either mean that a very small violation is rarely detected because it is difficult to observe and therefore a more severe violation is observed more easily or that enforcement efforts are increased and/or concentrated if there is a strong suspicion for a serious violation[17]. Moreover, increasing public enforcement expenditures although is meant to have a positive influence on the probability of detecting a non-compliant firm.

Including this leads to a more general setting, where a firm more continuously decides how much to pollute:

$$\text{a(s,S)} > \text{p(s,S,e)}\cdot\text{f(s,S)}$$

and the non-compliant firm operating at

$$\frac{\Delta a(s,S)}{\Delta s} = p(s,S,e)\frac{\Delta f(s,S)}{\Delta s} + \frac{\Delta p(s,S,e)}{\Delta s} f(s,S).$$

Heyes (2000) discusses a huge amount of further extensions of the model including firms investment to decrease inspectability, possible investments in effective lawyers, considering a multi-stage game, multiple polluters, self-reporting, multi-period and multi-context interactions and many more. Nevertheless, this paper will concentrate on the more or less basic model introduced so far in order to keep track of the underlying motivation, namely to reconnect the economic model of crime with the literature on compliance with environmental regulations.

To study compliance with environmental regulations in an aggregate setting, as it is often needed for empirical analysis, one can use the following cohesions already considered by Heyes (2000):

[17] Heyes (2000) also points out that a firm in return may invest in uninspectability meaning that a firm could be able to reduce p.

As already stated above, a firm will comply to a specific regulation, if c $\leq p() \cdot f()$. Assuming that c is distributed according to the cumulative distribution function F(c), the rate of compliance across all firms in society will be $F = F(c) = F(p \cdot f)$. This also means that the rate of non-compliance Θ can be described as

$$\Theta = 1 - F(p \cdot f) = 1 - F(\text{a(s,S)})=\text{1-F(p(s,S,e)}\cdot\text{f(s,S))}.$$

This leads to the following comparative statics:

$$\frac{\Delta\Theta}{\Delta p} = -F`f` < 0 \text{ and } \frac{\Delta\Theta}{\Delta f} = -F`p < 0.$$

That means increasing the probability of detection or the magnitude of the fine will lower the rate of non-compliance across all firms. Further on, using the assumptions already made above,

$$\frac{\Delta\Theta}{\Delta e} = -F`\frac{\Delta p}{\Delta e}f < 0.$$

This suggests that investing more in enforcement will also lower the rate of non-compliance. The next section now tries to connect both models in a consistent and tractable manner.

2.3 Bringing both models together

The aim of this section is now to incorporate the model of M&E into the more general economic model of crime. I will especially focus on the inclusion of the severity of punishment, the possibility of standards or switching points and the existence of imprisonment into this framework.

Switching point in this context means that there may be different points where a particular punishment scheme becomes relevant. Using environmental law as an example, there may be a pollution level whose excess will be treated as a simple regulatory misdemeanor and the offender therefore has to pay a fine or gets some specific burden. Furthermore, there may be another and superior pollution level from which on the violation will be treated as a serious crime. In this context, enforcement institutions will either resort to imprisonment alone or punishment means both fine/burden and imprisonment.

Assuming that firms are run by individuals, there are a few more assumptions one has to make in order to be able to bring both models together. The

relationship between the firm and the employee in the model for compliance can be seen as a Principal-Agent setting with the firm being the principal. Applying this setting causes no bias if principal and agent are able to reallocate fines and are not able to decrease total burden (see Polinsky & Shavell 2000/2005). In case where the employees response to public enforcement would be different from the optimal behavior suggested by the firm, firm and employee should be able to adjust contracts in a way that optimal decisions coincide. Moreover, if there is any possibility for principal and agent to avoid (at least parts of) the sanctions, then deterrence might be undermined. Polinsky & Shavell (2000) state that if the wealth constraints of the employee make it impossible to pay the fine, then principal and agent do not take the proposed amount of fine into account. Policy-makers then have either to resort to prison sentences or to impose the (remaining part of the) fine on the principal.

Another possible and important difference between enforcement in both models is due to the differences in available mechanisms. The literature on crime is usually, despite the simultaneity between different enforcement variables, a rather static setting. The criminal commits a harmful act whereupon public enforcement institutions react in any way (fine, burden and/or imprisonment). In the setting of environmental regulations, however, there is much more interaction taking place. Usually, if the enforcement agency (EPA in the U.S.A., GAA in Germany) has some suspicion that a firm may violate some legal standard it will in most cases first of all warn that firm. In this early stage, the firm has not been punished jet. The firm is now able to react to this detection. After the firms reaction, the agency can again react and either close proceedings if the firms now complies or impose a fine or burden if the firm still violates. After all, if a firms violation lasts for a long time or the violation is very severe the agency may forward the case to prosecutors and the responsible may get another fine and/or a prison sentence. To conclude, this is more a dynamic setting with very much interaction taking place and one has take this into account when reconnecting both models. However, this kind of dynamic interaction is usually only appropriate in context of firms, rarely in the context of a pure individual setting.

In contrast, a easily seen connection between the economic model of crime and the model for compliance with environmental regulations is that g() equals c or a(), respectively, i.e. the gain through offending environmental laws or regulations usually equals the cost of compliance one would have to pay (see section 2.2). This implies that the gains through the illegal act

could in the more general setting also depend on some standard S. With the actual pollution level being far above the standard S the violator safes a higher amount of compliance costs. Furthermore, standards/switching points may also influence enforcement and punishment activities. If one thinks of tax evasion, there might be a point up to which one just has to remargin taxes. However, if this point is passed, tax evasion might be seen as a simple misdemeanor and might additionally entail a fine. Moreover, the amount of evaded taxes being substantial, the violation might be seen as a serious crime and might even lead to imprisonment. In this context, switching points could differ from violation to violation and could also be 0 for serious crimes. This reflects the fact that there is no point up to which rape, assault or murder is no criminal act. Nevertheless, s is also meant to vary for all kinds of violations. There are even circumstances where one homicide is more severe than the other, e.g. if the element of cattiness is fulfilled.

Thinking the other way round and as already mentioned in previous sections, criminalizing environmental offenses should entail the inclusion of the possibility of a prison sentence into the model. Including the possibility of imprisonment further leads to incorporating the probability of getting a fine p_m or getting arrested p_a. Further on, and as already developed in this section, there is the possibility of different switching points S_d, S_m, S_a for different punishment schemes. Merging all this tells us that a individual will engage in a illegal activity, if:

$$\mathrm{g(s,S}_d,S_m,\mathrm{S}_a) > \mathrm{p}_d(s, S_d, e)[p_m(s, S_m, e)f(s, S_m) + p_a(s, S_a, e)d(t(s, S_a))],$$

with $S_a \geq S_m \geq S_d$. The rate of non-compliance or crime rate can then be illustrated as:

$$\Theta = 1 - F(\mathrm{g(s,S}_d,S_m,\mathrm{S}_a))=1-$$
$$\mathrm{F}(p_d(s, S_d, e)[p_m(s, S_m, e)f(s, S_m) + p_a(s, S_a, e)d(t(s, S_a))])$$

The next section now highlights important policy-variables found so far for both models. For either model I will first of all explain the typical empirical estimations equations in a broader setting and then concentrate on important policy-variables providing evidence for the effectiveness of enforcement.

3 Empirical Insights

So far, the empirical as well as the theoretical literature on environmental regulation and crime were strongly separated. With the last section having focused on theoretical aspects, it will now be the aim of this section to discuss and contrast empirical methodologies usually applied and insights already attained.

3.1 The economic model of crime

The empirical version of the economic model of crime in most cases is at the aggregate level[18] and looks very similar to the following:

$$\ln\left(\frac{Q}{N}\right) = A + \beta P + \gamma S + \delta Y + \epsilon,$$

where Q reflects the number of offenders/offenses, N the number of targeted people (together known as crime rate), A is some constant and P is a vector containing variables affecting the probability of different punishment schemes. Furthermore, S is a vector consisting of variables indicating the severity of punishment, Y is a vector for socioeconomic factors and β, γ, δ and ϵ stand for the parameter vectors to be estimated and the disturbance, respectively.

P again does often contain variables like the police force and/or detection, conviction and/or arrest rates. S usually includes either the amount of prison population or the average length of imprisonment with the latter seeming to be more obvious for most purposes. Y can contain very different socioeconomic factors, ranging from unemployment over gender to minority fractions, education, wages, population density or different income (distribution) variables. In nearly all papers, crime rate is used in logarithmic form whereas the other variables being transformed only in some cases.

There are quite a few problems one has to deal with when engaging in the empirical version of the economic model of crime. The first suggestion one comes up with when looking at crime rates is the possibility of a dark figure. Nobody can make sure that every offense will be observed and then also reported to and recorded by official authorities[19]. Depending on which factors

[18] just because data on individual level is rarely available to researchers; exceptions are Witte (1980), Myers (1983), Grogger (1991) and some more.

[19] There are two main reasons why a crime may not be included in official statistics. First there is the possibility that a potential crime is not recorded to the police. The reason for

influence the amount of a dark figure, there might be a great measurement error bias when ignoring this. It may e.g. be the case that increasing police force just leads to a reduction of dark figures, not a reduction in the amount of crime itself. Neglecting the existence of the dark figure then results in a spurious negative effect of police on crime. There are two possible characteristics of a dark figure that could result in biased estimators. As Eide (1999) points out, the regional and temporal reporting or recording behavior could not be constant and thus yield biased estimates. Further on, there should also be a problem if the dark figure depends on any kind of variable explaining crime (see McDonald, 2002). If either is the case, however, it will be questionable if results are reliable. There is some, but not much work done so far to answer this question and I will give a brief introduction into this topic.

MacDonald (2001/2002) addressed this question trying to find the determinants of non reporting via data from the British Crime Survey (BCS). His aim is to figure out, which of the time varying variables do have a (statistically) significant influence on reporting behavior. He uses microeconometric (probit) analysis and finds that variables like unemployment and age have a significant effect on the decision whether to report or not. He concludes that researchers should take these factors into account when estimating the economic model of crime.

Another study dealing with this question and also using BCS data and data from the British General Household Survey (GHS) is the one by Pudney et al. (2000). They use a error correction model (ECM) and Monte Carlo simulation methods to identify the biases for the estimates on the probability of conviction resulting through under-recording. The authors find measurement errors as "statistically significant, but in most cases negligible for all practical purposes" (Pudney et al., 2000, p.96). Measurement errors seem to be systematic and multiplicative and only slightly problematic for con-

this may either be that the crime was not oberserved by anyone or it has been observed but not recorded to any authority. Naturally, one is not able to say anything about the amount of the former. According to the annual conducted British Crime Survey (BCS), however, the latter amounts of 57% of all crimes in 2004; see Nicholas (2005). The U.S. counterpart to the BCS, the NCVS, finds also merely constant, but little reporting behavior in the American population. In 2004, 41.5% (40.5% in 2003) of all victims reported the violation to the police with great variation between various offenses.

The second source for a dark figure may be that crimes are observed and reported to police but not recorded by any official authority. This may be due to procedual error, human failure, etc.. However, this should not be a significant part of criminal activity.

viction rates. However, this results being true for England and Wales are no evidence that there are also no problems for other countries and other deterrence variables.

From my point of view, there is still a lot work to do in order to extract the effects of under-recording on the estimation of the economic model of crime. Moreover, it would also be interesting to learn more about the nature and characteristics of dark figures incorporated in different crime statistics.

Furthermore, various kinds of endogeneity play a crucial role in extracting the 'true' causal relationship within Becker's (1968) model. The majority of previous work did therefore concentrate on problems like simultaneity and unobserved heterogeneity[20].

There exists a huge empirical literature dealing with the problem of simultaneity, in particular for deterrent variables, in the economic model of crime[21]. Within this literature, there is to some extend consensus regarding the deterrent effect of different crime-control policies like police force or severity of punishment. However, most researchers also agree upon the influence of crime on crime control policies. In most cases, a higher presence of police forces or more severe penalties should yield less criminal activities. As a result, with recognizing more crimes, the officials will be tempted either to increase the amount of police or the severity of punishment, or both. Another possible effect is the reduction of the probability of apprehension via a rising crime rate which results e.g. through a capacity overload of police forces. Whereas the first and third effect result in a negative relation between crime and deterrence, the second effect lasts in a positive relationship. One will therefore get biased estimates, if this issue is not attended in a capable manner. As expected, simultaneity seems to be a topic one has to take care of and results seem to be more reliable if simultaneity is explicitly modelled. Many of the prior papers estimating the deterrence effect of different enforcement variables did not model simultaneity and therefore merely found a positive connection between deterrence variables and crime[22]. In contrast, more recent studies being aware of possible simultaneous effects predominantly find

[20] Additionally, Mustard (2003) stresses the problem of omitted variables bias in the economic model of crime.

[21] see Ehrlich (1973), Cornell & Trumbull (1994), Andreoni (1997), Bar-Gill & Harel (2001), Viren (2001), Mustard (2003), Levitt (2002b), Gould et al. (2002), DiTella & Schargrodsky (2004), Evans & Owens (2006), Baltagi (2006) and many others; for an additional overview see Cameron (1988), Levitt & Miles (2004) and Almer (2007).

[22] see Cameron (1988).

evidence for deterrence in the economic model of crime[23].

Another source of endogeneity is the unobserved heterogeneity between different observation units (individuals, industries, counties, states, nations, etc.). Cornwell & Trumbull (1994) and Cherry (1999) addressed this question arguing that most studies until then just used cross-sectional analysis and thus were not able to control for unobserved heterogeneity. In their analysis, Cornwell & Trumbull (1994) dealt with both sources of endogeneity, simultaneity and unobserved heterogeneity, using panel data structure and a simultaneous equations model. Reestimated by Baltagi (2006), all three studies find unobserved heterogeneity being a crucial problem when estimating the economic model of crime. Cherry (1999) estimates a pooled model and compares the results with appropriate random and fixed effects panel data estimates. Correspondingly to Cornwell & Trumbull (1994) the author finds significantly different results for both models stating the upward bias for the probability of arrest resulting through unobserved heterogeneity to be at about 20% for all crimes. In addition, Cherry (1999) extends his analysis with estimating the model for different types of crime separately. Doing this, the authors finds biases ranging from 0% for robbery to 70% for burglary.[24]

3.1.1 Important policy-variables

This section is a brief summary of the evidence found so far for the economic model of crime. I will concentrate mainly on deterrence variables since these are most interesting for our further analysis. Nevertheless, I will also shortly summarize the effects socioeconomic factors have on crime rates, since this is a steadily increasing field in Law and Economics literature. As already stated, this is a brief summary since the huge amount of empirical papers would go beyond the scope of this article[25].

First of all I want to address the effect of a increasing probability of punishment. Although, there are quite a few measures for this. Many studies just use direct probabilities like the arrest, conviction or imprisonment rate. There are very little studies using the detection rate as an deterrence variable.

[23] see Levitt & Miles (2004) and Almer (2007).

[24] for a more detailed discussion and further problems associated with the estimation of Becker's (1968) model of crime, like time lags or aggregation biases, see Almer (2007).

[25] for a more detailed discussion of this topic, see Levitt & Miles (2004) and Almer (2007).

The detection rate thereby reflects the portion of offenders that are identified by legal authorities. This does not coercively imply that this offender will also be punished but it should not be in the interest of the offender to be detected. In contrast, the conviction, arrest and imprisonment rate directly imply that this portion of offenders already received some kind of punishment but does not tell anything about the severity or the length of the punishment, respectively.

Another variable, namely police force[26], is more a determinant of the probability of punishment. However, it should have a direct influence on the detection and also arrest rate, whereas the conviction and imprisonment rate should rather be affected by the amount of prosecutors and judges, respectively[27]. The last deterrence variables I want to review are variables reflecting the severity of punishment like average prison length or prison population.

Direct measures of the probability of punishment, such as the arrest, conviction and imprisonment rates nearly all have the expected negative sign and are significant in most cases[28]. It is getting more difficult when one tries to examine the causal effect of police force on crime. Nevertheless, after controlling for simultaneity, the effect of police on crime appears to be negative as well[29].

The same is true for the severity of punishment represented by the average length of imprisonment or prison population. The varying effects on crime mostly disappear if the problems of simultaneity and incarceration[30] are included in the empirical analysis[31]. To conclude, there seems to be clear evidence for deterrence in the economic model of crime.

As with deterrence, it looks like socioeconomic factors also having a im-

[26] or the amount of other professional guilds in the legal system, like civil servants or traffic wardens etc..

[27] but data on the amount of prosecuters and judges is rarely used in practice

[28] see Ehrlich (1973), Cornwell & Trumbull (1994), Andreoni (1997), Cherry (1999), Viren (2001), Gould et al. (2002), Cherry & List (2002) and Baltagi (2006).

[29] see Marvin & Moody (1996), Levitt (1997), Levitt (2002b), Cherry & List (2002), Corman & Mocan (2002), Di Tella & Schargrodsky (2004), Klick & Tabarrok (2005) and Evans & Owens (2006).

[30] longer average prison lengths or an increasing prison population may just lead to less crime, because potential criminals are incarcerated.

[31] see Ehrlich (1973), Levitt (1996), Andreoni (1997), Marvell & Moody (1994), Corman & Mocan (2000) and Bar-Ilan & Sacerdote (2004).

portant effect on crime[32]. However, this is not true for all variables. Unemployment seems to have only a significant positive effect on property crimes, the effect on violent crimes is sometimes even negative. Albeit the latter is not as easy to explain, the former is in line with general suggestions. Labor force participation is not very often included in previous studies and has no definite effect overall. However, there seems to be a very clear-cut negative effect of income inequality on crime. There is only one paper that finds different results for some specifications. In contrast, wages and education cannot be seen to have any clear-cut relation to criminal behavior.

Overall, most empirical implementations of the economic model of crime confirm Becker's (1968) suggestions. The probabilities of getting caught, being convicted or getting arrested, and the expected severity of punishment do all deter from criminal activities. Hence, there is a apparent evidence for the deterrence effect of law enforcement. Socioeconomic variables as a reflection of the possible benefits of crime or its legal substitutes also show to have a important impact on crime. Especially inequality seems to attract criminal behavior.

3.2 The model on enforcement and compliance

Simultaneous to the theoretical literature on compliance with environmental regulations there grew the empirical counterpart estimating what is commonly called compliance, penalty and enforcement functions (see Heyes, 2000). The questions in this context are very similar to the ones in crime literature, namely, if greater enforcement efforts and a more severe punishment really lead to greater compliance. In comparison to Becker's (1968) model, there are relatively few empirical papers published that stress this topic. Cohen (1998) points out that this may due to huge data constraints researcher face in this context. Although the U.S. EPA is more and more making relevant data available for researchers, data is still very scarce in other countries.

The typical estimation equation for compliance with environmental regulations, although not as homogenous as in the general economics of crime literature[33], very often has the following form:

[32] see Almer (2007) for an overview.

[33] in this literature, the authors often look at very different settings and industries. Examples include the enforcement in case of oil spills, nuclear power plants, pollutions regulation for steal industry, paper industry, etc..

$$Q = A + \beta P + \delta Y + \varepsilon,$$

where Q stands for the level (or the duration[34]) of the harmful activity (e.g. oil spills, pollution, etc.), P for a vector of different M&E activities and Y for a vector of firm specific characteristics. A, β and δ are the parameter vectors to be estimated. This is the model which is nearly identical to the ones used in the economics of crime literature. Furthermore, there were also great efforts to get a better understanding of governmental enforcement behavior and their effectiveness. Researchers therefore developed penalty and enforcement functions that mostly have the following forms:

$$S = A + \beta P + \lambda T + \delta Y + \varepsilon \text{ and}$$

$$P = A + \lambda S + \delta Y + \varepsilon,$$

where S stands for the penalty, P for different monitoring activities, T for the vector of variables reflecting severity of the violation, Y for firm and region specific characteristics and A,β, λ, δ and ε again for the parameter vectors to be estimated and the disturbance, respectively.

Many of the empirical shortcomings researchers found in the context of the economic model of crime were are also stressed in the literature dealing with environmental regulations. The possibility that a violation is not observed by any legal authority, meaning that there exists a dark figure, is clear to everyone. In comparison to crime literature, however, it is even more difficult to light the dark figure since many violations are not observed by anyone except the violator. At least to some extend and for some types of crime, some countries try to measure the real amount of crime via comprehensive and periodical victim surveys[35]. This is in many cases not possible for environmental offenses since there is often no direct victim or no definite amount of victims.

Researchers analyzing firms compliance with environmental regulations also are aware of potential simultaneities. Gray and Deily (1996), e.g. find that greater enforcement results in greater compliance and greater compliance leads to less enforcement. Additionally, Helland (1998) tries to answer the question, whether firms being found in violation face a higher probability of inspection. The answer to this question can be responded with yes.

Furthermore, Magat and Viscusi (1990) stress the possibility of time lags that could exist in the relationship between different enforcement, deterrence

[34] see Nadeau (1997)

[35] e.g. the BCS in UK and NCVS in the U.S.A.

and compliance variables[36].

Since the strand of literature is not as extensive as in crime literature, there is also less work done regarding problems arising through empirical estimation. Nevertheless, almost all problems associated with empirical crime literature can be carried over to the estimation of enforcement and compliance.

3.2.1 Important policy-variables

In this section I will now focus on important policy-variables found to be relevant for environmental regulations. In contrast to the more general crime literature, researchers used different approaches to examine important causal relationships. As already mentioned above, one can range most of the work done so far into three basic functional forms. I will first of all review the literature dealing with functions explaining compliance before I switch to penalty and enforcement functions.

Compliance Function

One of the most important policy-variables in this context is the amount of monitoring a firm faces. The more often or more accurate monitoring takes place, the higher is the probability that a violation is observed. Monitoring is therefore meant to reflect the probability of detection and thus the probability of getting punished in either way (fine, imprisonment, etc.). Epple & Visscher (1984) use several monitoring variables finding that increasing monitoring leads to lower oil spills. Cohen (1987) uses a very similar approach and additionally is able to examine that monitoring has a clear deterrent effect although with variations for particular variables. The author finds that monitoring oil transfer operations and random port patrols seem to have the highest deterrence effect whereas the effect of routine inspections seems to be negligible. Viladrich-Grau & Groves (1997), using more detailed data, estimate the effect of monitoring to be larger for oil spill frequency than for spill size. Magat and Viscusi (1990), analyzing compliance for the U.S. pulp and paper industry with water pollution regulations, confirm previous results and additionally are able to designate a one quarter time lag for the positive effect of EPA enforcement actions on compliance. However, Cohen

[36] there is also a huge amount of studies stressing this issue in crime literature, see Marvell & Moody (1996), Corman & Mocan (2000) and many more.

(1987) refers to a study by Liu (1995) who uses updated data and finds no clear-cut evidence for the deterrence effect of EPAs monitoring efforts. Liu (1995) divides monitoring into two types, discretionary and routine. In this analysis, routine inspections seem to increase the number of known violations and only discretionary monitoring has the expected negative effect.

Laplante & Rilstone (1996), using an approach very similar to Magat & Viscusi (1990), confirmed their results for Canadian data. The authors estimate both a positive effect of inspections on compliance and on frequency of self-reporting[37]. Gray & Deily (1996) using data for U.S. steel industry and EPA's enforcement efforts again estimate a positive effect of monitoring on compliance.

Furthermore, Cohen (1987) refers to Sullivan (1987), Fullerton & Kinneman (1995) and Sigman (1998) who examine the effect prices have on illegal waste disposals. According to Cohen (1987), they all conclude that increasing prices for waste disposals increase the amount of illegal disposal.

Nadeau (1997) uses duration analysis trying to extrapolate the effect of monitoring and enforcement on the length of non-compliance. The author estimates that a 10% increase in monitoring and enforcement leads to a 0,6% to 4,2% and 4,0% - 4,7% reduction in violation time, respectively.

To conclude, nearly all of the reviewed empirical work supports the hypothesis that more/tighter M&E and therefore a higher probability of being detected leads to greater compliance.

Penalty Function

Cohen (1987) estimates a penalty function that amongst others also includes indicators for the severity of the violation like spill size, type of oil, etc.. The author also assumes that the probability of detection depends on the size of oil spills, monitoring technology and level of enforcement as already mentioned in the theoretical part of this paper. The author finds a positive and significant relation between spill size and resulting penalty, whereas the sign of the enforcement variables varies with the chosen specification. Cohen (1987) also proofs the penalty to depend on the cause of spill and finds that intentional spills increase the penalty quite heavily. Cohen (1978) thereupon concludes that coast guard uses negligence rather than strict liability standards. In addition, Lear (1998) uses pollution data from EPA and concludes that fines rise with the expected gain a firm gets from

[37] this is in line with Helland (1998).

violating some pollution standard.

Enforcement Function

Deily & Gray (1991) estimate a function that explains government inspection behavior in the U.S. steel industry. Among others they also include variables for past pollution levels and compliance costs. Whereas compliance cost do not have a significant impact, past pollution has. The higher the level of past pollution, the more monitoring and enforcement activities a firm will face. Dion et al. (1998) use a very similar model to describe Canadian enforcement behavior with respect to pulp and paper industry. The authors are able to extrapolate a negative effect past compliance has on enforcement. Furthermore, they also confirm the thesis that large damages lead to a further inspections.

4 The specific characteristics of German environmental law

German environmental law is a very widespread area of legal activity. Prescriptions regarding the environment are found in the German constitution, the German criminal code, state laws and regulations and many more. Furthermore, there are also several institutions enforcing environmental law in Germany. Environmental offenses may be recorded by the police, prosecutors, administrative authorities (GAA) and custom investigation.

Another specific feature of German environmental law is its administrative accessoriness (Verwaltungsakzessorietät). This means that the decision whether a particular behavior is legal or not is not always defined ex ante but is sometimes administrative discretion. As one can see, neither the law itself nor its enforcement has a clear-cut structure. Germany therefore recently tries to adopt a uniform environmental code in order to make things more tractable. Nevertheless, it should be interesting to get a better understanding of the activities of the different enforcement agencies and their punishment schemes.

For example, the main but decreasing (86% in 1998, 70% in 2003[38]) part of all lawsuits regarding violations of environmental law in Germany are initi-

[38] Statistisches Bundesamt (2003).

ated by police. Theses cases may result from a hint given by some citizen[39] or from a discovery made during patrol. A smaller but steadily rising part is initiated by prosecution (11% in 1998, 25% in 2003). One question is, whether this part reflects the more severe offenses since prosecution is not responsible for regulatory offenses. A very small but also increasing fraction is initiated by administrative authorities (1,8% in 1998, 3,2% in 2003). In case of environmental offenses the main part should be due to the Gewerbeaufsichtsamt and should therefore reflect the fraction of violations committed by firms. Finally, a more or less negligible part is initiated by custom investigation (0,3% in 1998, 0,6% in 2003).

These special characteristics make even more complicated to understand how enforcement works in environmental law, and how effective it is. It is therefore a interesting topic to analyze the functioning of German environmental policy in more detail since this has not been done adequately until now.

5 Outlook

There is still a lot work to do in order to close the existing gap between the economic model of crime and enforcement & compliance literature. This holds for the theoretical as well as for the empirical literature. In this section, however, I want to limit the scope to the discussion of the empirical problems, in particular for those in Germany.

First of all, and this may be very obvious, it would be interesting to learn more about how the enforcement and deterrence of environmental law works in general (for Germany). So far, empirical studies analyzed the deterrence effect of different felonies or serious property crimes for whole states or countries but did not consider environmental offenses. On the other hand, studies dealing with environmental offenses focused on the compliance of firms with environmental regulations. This obvious gap could be closed by analyzing the economic model of crime for environmental law and thereby taking the special characteristics of (German) environmental law into account.

Another open question stresses the embedding of environmental law in general criminal law in 1980 in Germany. Many German researchers in Law literature think that this was wrong[40]. The fact that criminal law is rarely ap-

[39] or even from some other governmental institution.

[40] Schall (2006) gives on overview of related work.

plied to environmental offenses causes them to conclude that this embedding was effectless. Economists in contrast would rather ask if this embedding did yield less crime or less severe crime in order to rate its effectiveness. The simple existing of a lack of enforcement (Vollzugsdefizit) should not automatically be considered as evidence for a failure of criminal law.

Further on, what determines if a offender has to pay a fine or gets a prison sentence, i.e. what determines the classification of a violation either as a simple misdemeanor or a serious crime? Is it the severity of the violation in form of damage caused, gain attained or something else? Which role do different governmental institutions like the police, environmental agencies, prosecution etc. play in this decision process? To what extend is the possibility of imprisonment used in context of environmental offenses?

The last question I want to stress here is more a rhetorical one. What role does this already mentioned Verwaltungsakzessorietät play for enforcement of environmental law in Germany? Does it yield great differences between different regions? A first look at data at least confirmed the hypothesis that there are great regional differences.

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